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Eguchi

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(54) **VERIFICATION APPARATUS, VERIFICATION PROGRAM, AND VERIFICATION METHOD**

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G06F 21/32	(2013.01)
H04L 9/32	(2006.01)

(52) **U.S. Cl.**

CPC ***H04L 9/3231*** (2013.01); ***G06F 21/32*** (2013.01)

(58) **Field of Classification Search**

CPC G06F 21/32; G07C 9/00071–9/00087; G07C 2009/00095; G07C 9/00158

USPC 713/186; 382/115

See application file for complete search history.

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(57) **ABSTRACT**

In a verification apparatus, a biometric information acquisition unit acquires a plurality of biometric information pieces from an object. A first verification unit calculates, as a verification score, the similarity between the biometric information piece and a verification information piece, and compares the calculated verification score with a first determination value to determine whether the biometric information piece matches the verification information piece. When the verification fails, a second verification unit performs verification on the plurality of biometric information pieces having a predetermined relationship, using the verification information piece and a second determination value which defines a less stringent criterion than the first determination value. The second verification unit compares the verification score with the second determination value, and determines that the match is confirmed when a plurality of biometric information pieces satisfy the criterion defined by the second determination value.

6 Claims, 18 Drawing Sheets

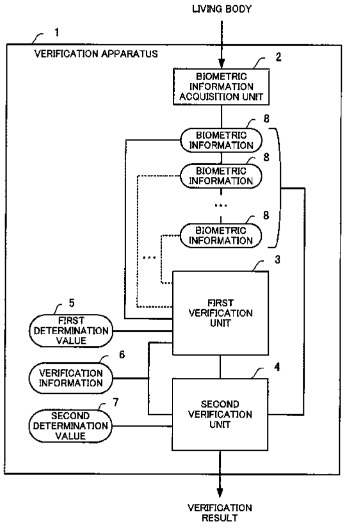

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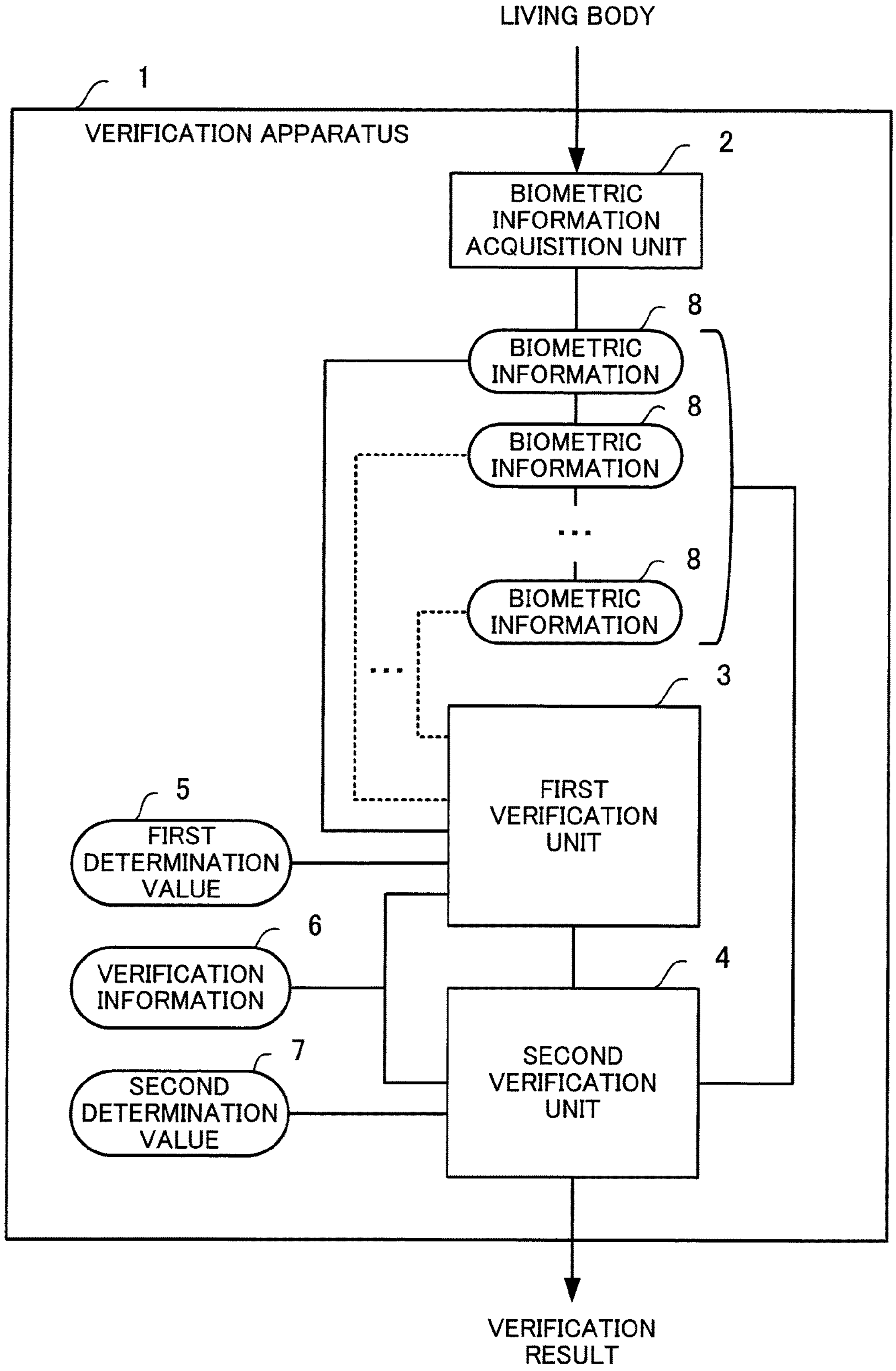
FIG. 1


LIVING BODY
1
VERIFICATION APPARATUS
2
BIOMETRIC INFORMATION ACQUISITION UNIT
8
BIOMETRIC INFORMATION
8
BIOMETRIC INFORMATION
8
BIOMETRIC INFORMATION
3
FIRST VERIFICATION UNIT
5
FIRST DETERMINATION VALUE
6
VERIFICATION INFORMATION
4
SECOND VERIFICATION UNIT
7
SECOND DETERMINATION VALUE
VERIFICATION RESULT

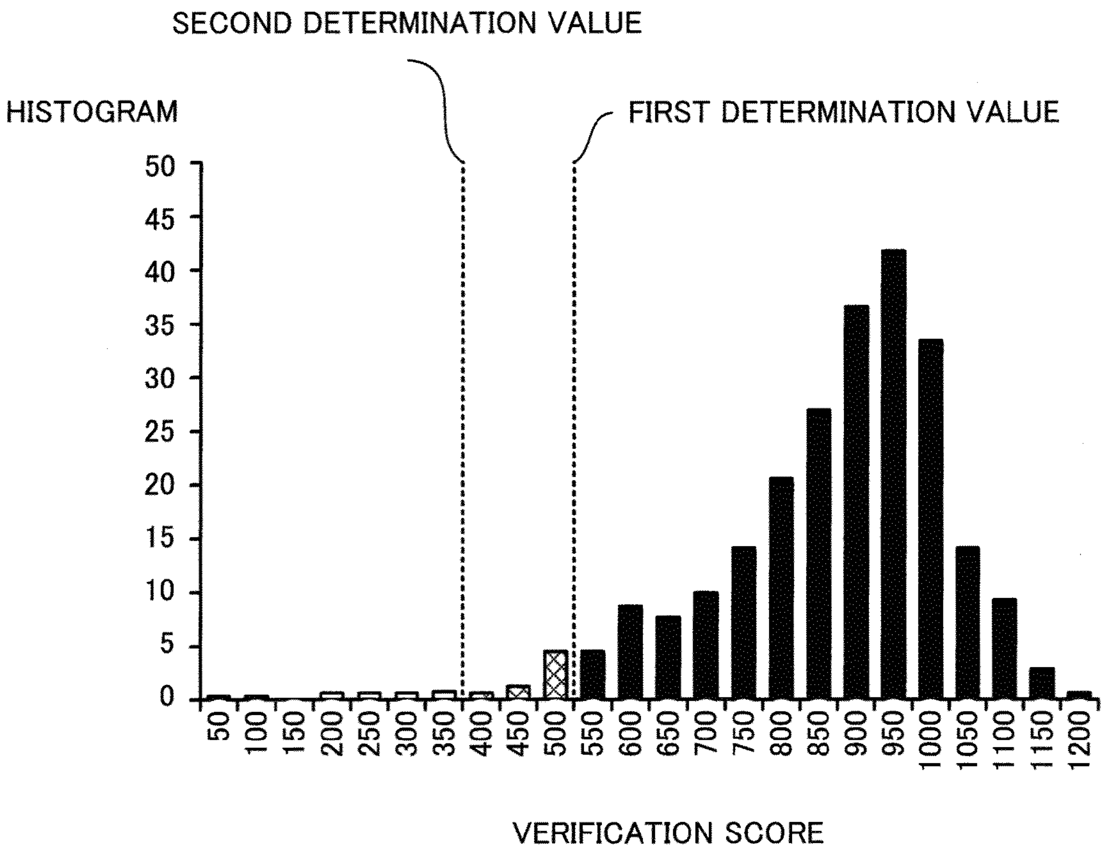

SECOND DETERMINATION VALUE
HISTOGRAM
FIRST DETERMINATION VALUE
50
45
40
35
30
25
20
15
10
5
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
1050
1100
1150
1200
VERIFICATION SCORE

FIG. 2

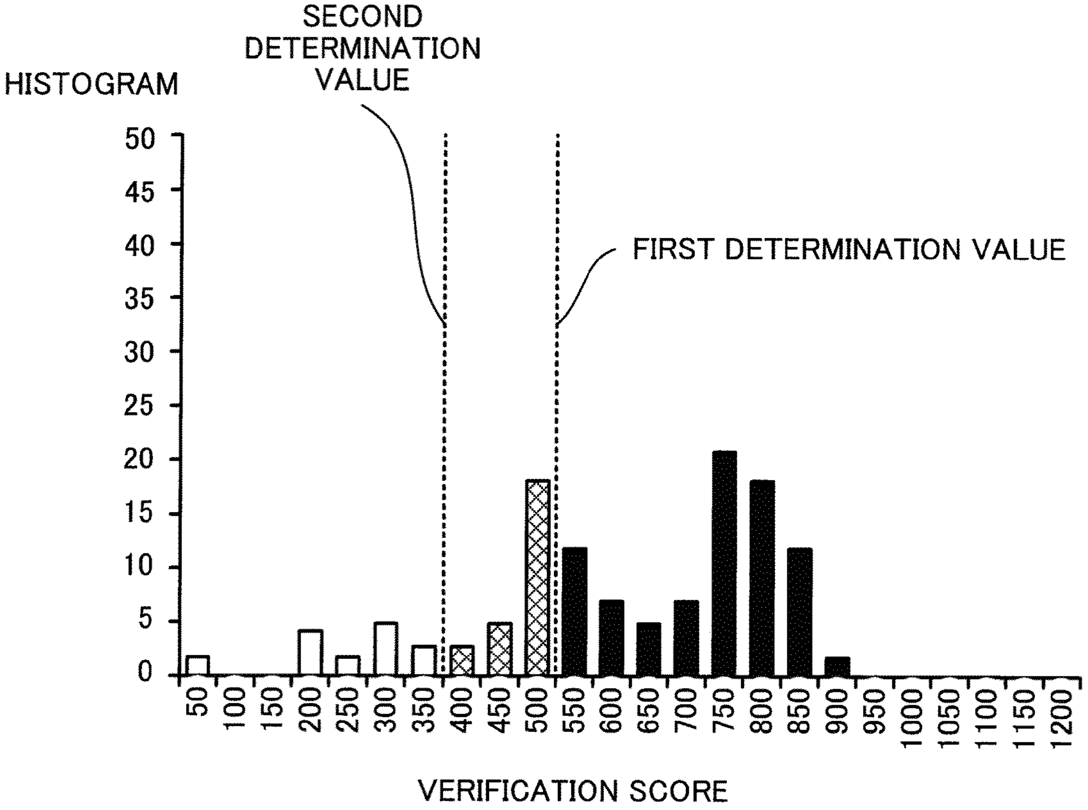
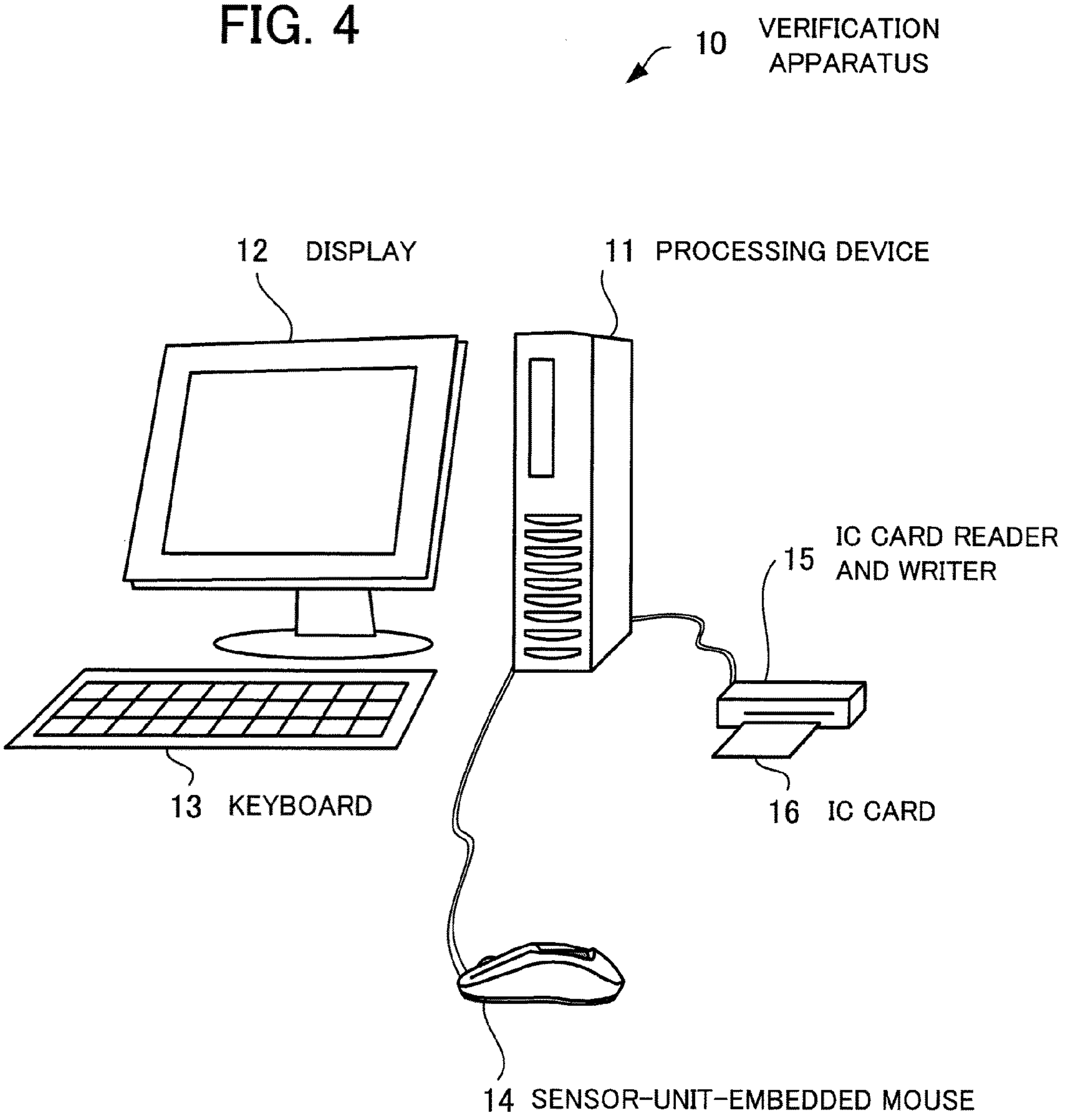

SECOND DETERMINATION VALUE
HISTOGRAM
FIRST DETERMINATION VALUE
50
45
40
35
30
25
20
15
10
5
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
1050
1100
1150
1200
VERIFICATION SCORE

FIG. 3

FIG. 4


10 VERIFICATION APPARATUS
12 DISPLAY
11 PROCESSING DEVICE
15 IC CARD READER AND WRITER
13 KEYBOARD
16 IC CARD
14 SENSOR-UNIT-EMBEDDED MOUSE

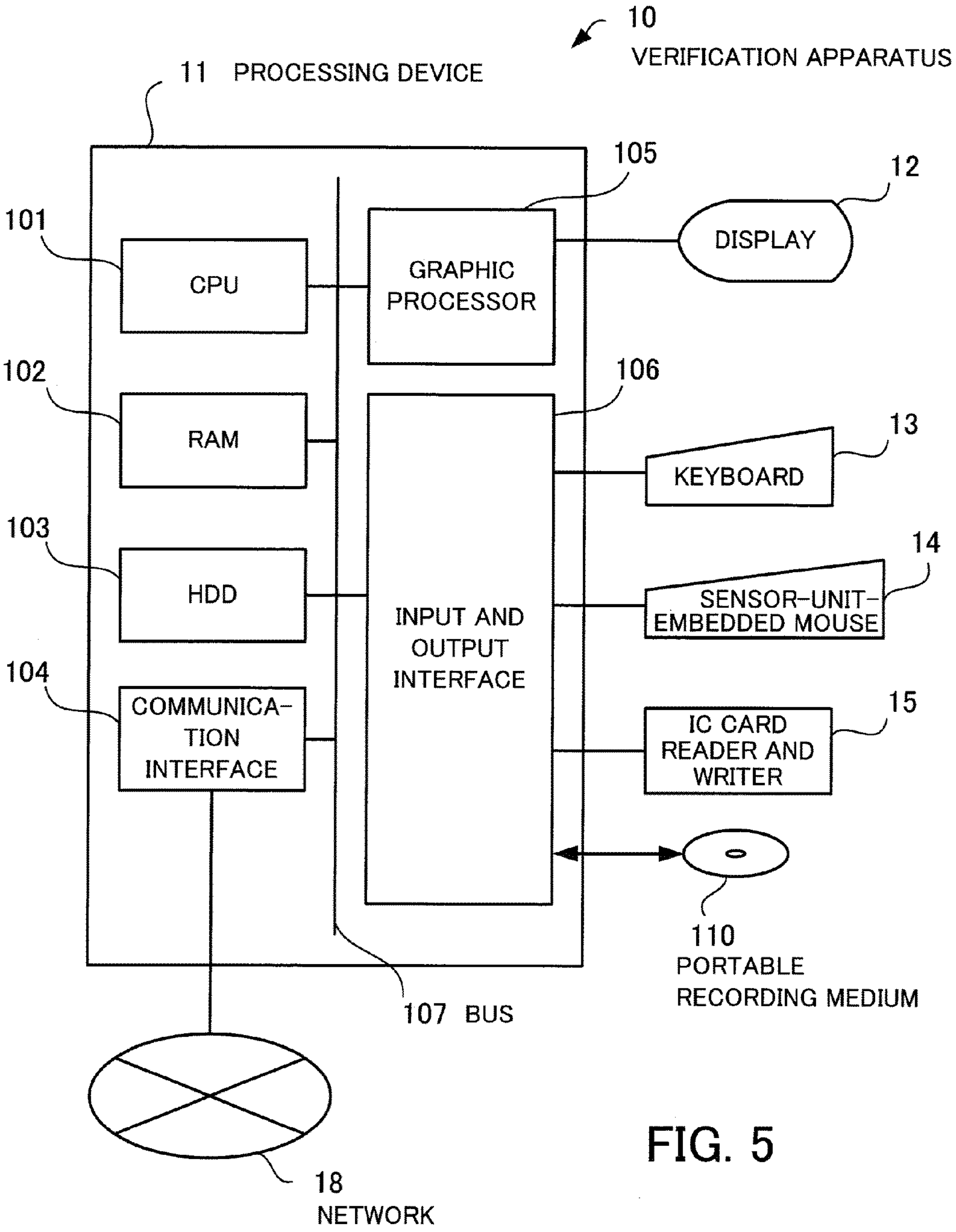

10
VERIFICATION APPARATUS
11 PROCESSING DEVICE
101
CPU
102
RAM
103
HDD
104
COMMUNICA-
TION
INTERFACE
105
GRAPHIC
PROCESSOR
106
INPUT AND
OUTPUT
INTERFACE
12
DISPLAY
13
KEYBOARD
14
SENSOR-UNIT-
EMBEDDED MOUSE
15
IC CARD
READER AND
WRITER
110
PORTABLE
RECORDING MEDIUM
107 BUS
18
NETWORK

FIG. 5

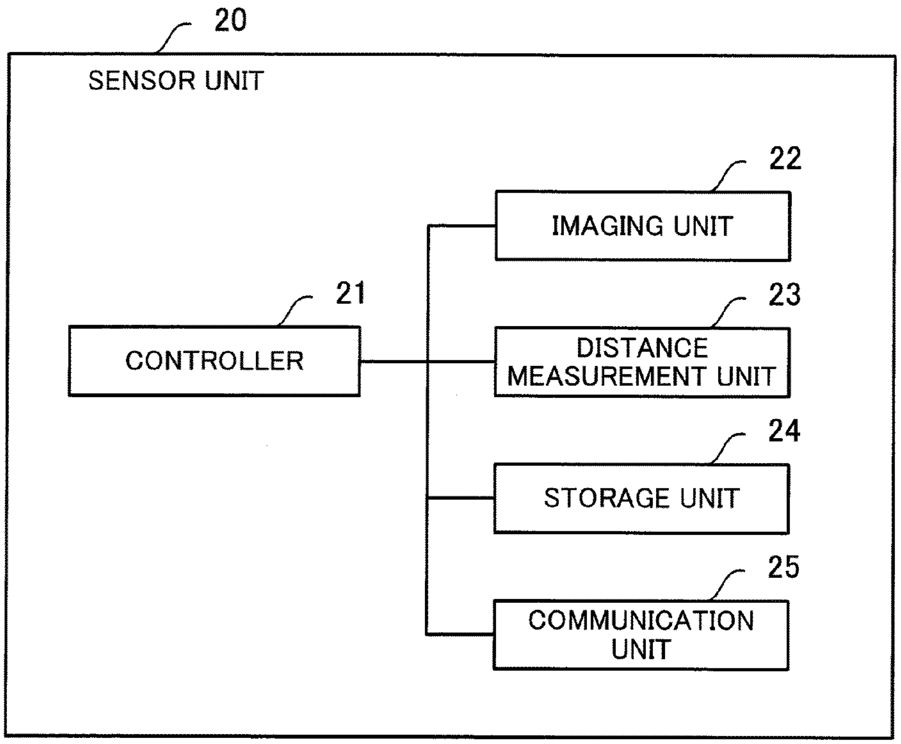

20
SENSOR UNIT
22
IMAGING UNIT
21
CONTROLLER
23
DISTANCE MEASUREMENT UNIT
24
STORAGE UNIT
25
COMMUNICATION UNIT

FIG. 6

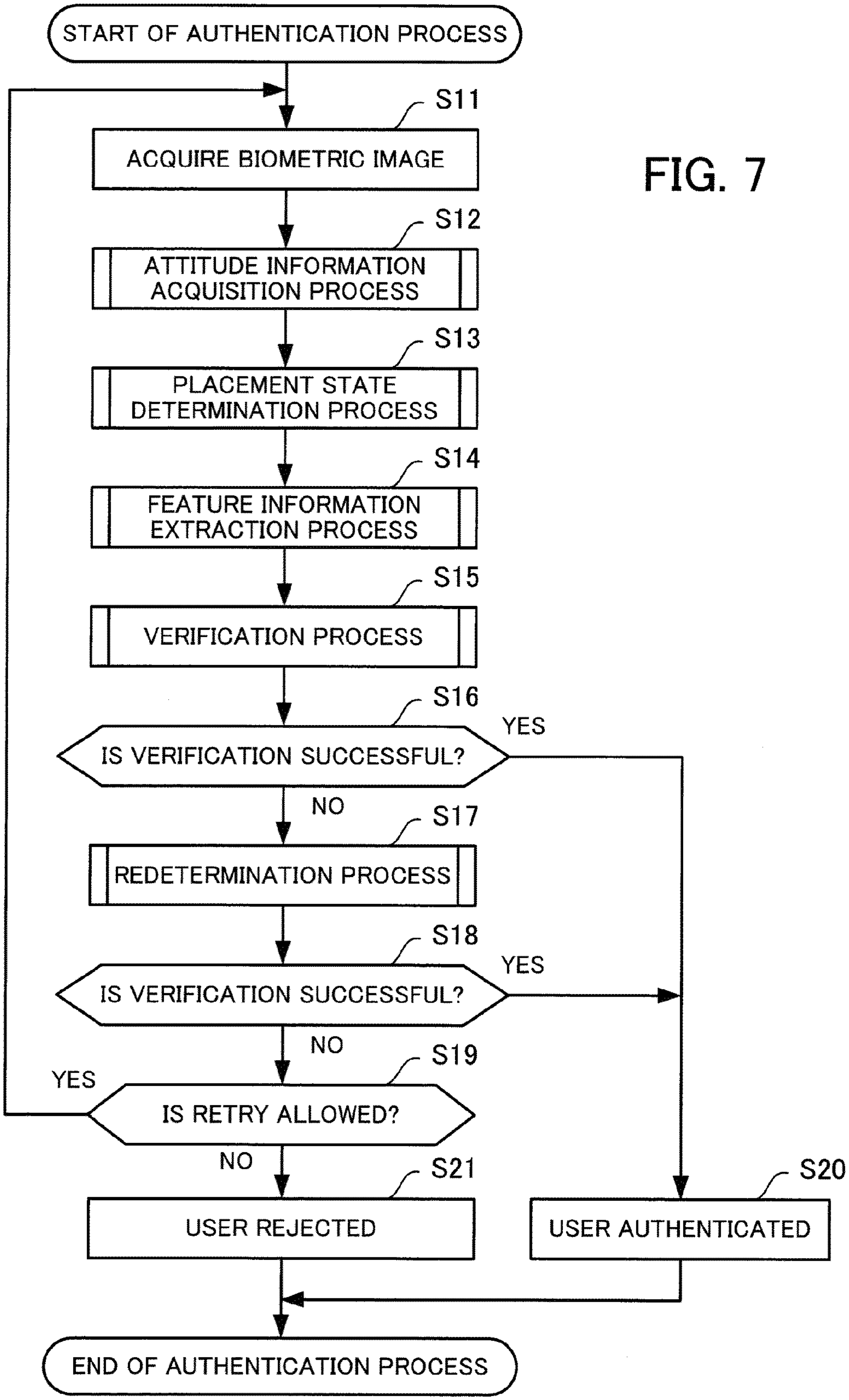

START OF AUTHENTICATION PROCESS
S11
ACQUIRE BIOMETRIC IMAGE
S12
ATTITUDE INFORMATION ACQUISITION PROCESS
S13
PLACEMENT STATE DETERMINATION PROCESS
S14
FEATURE INFORMATION EXTRACTION PROCESS
S15
VERIFICATION PROCESS
S16
IS VERIFICATION SUCCESSFUL?
YES
NO
S17
REDETERMINATION PROCESS
S18
IS VERIFICATION SUCCESSFUL?
YES
NO
S19
YES
IS RETRY ALLOWED?
NO
S21
USER REJECTED
S20
USER AUTHENTICATED
END OF AUTHENTICATION PROCESS

FIG. 7

FIG. 8

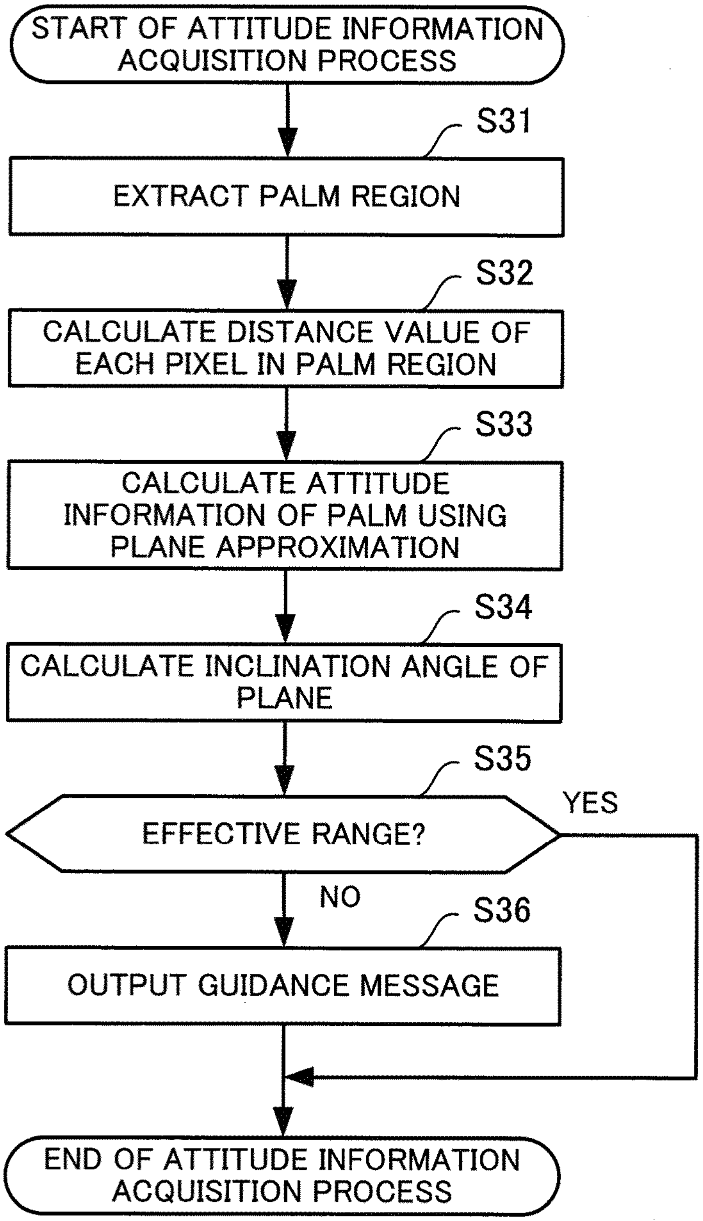

START OF ATTITUDE INFORMATION ACQUISITION PROCESS
S31
EXTRACT PALM REGION
S32
CALCULATE DISTANCE VALUE OF EACH PIXEL IN PALM REGION
S33
CALCULATE ATTITUDE INFORMATION OF PALM USING PLANE APPROXIMATION
S34
CALCULATE INCLINATION ANGLE OF PLANE
S35
EFFECTIVE RANGE?
YES
NO
S36
OUTPUT GUIDANCE MESSAGE
END OF ATTITUDE INFORMATION ACQUISITION PROCESS

FIG. 9

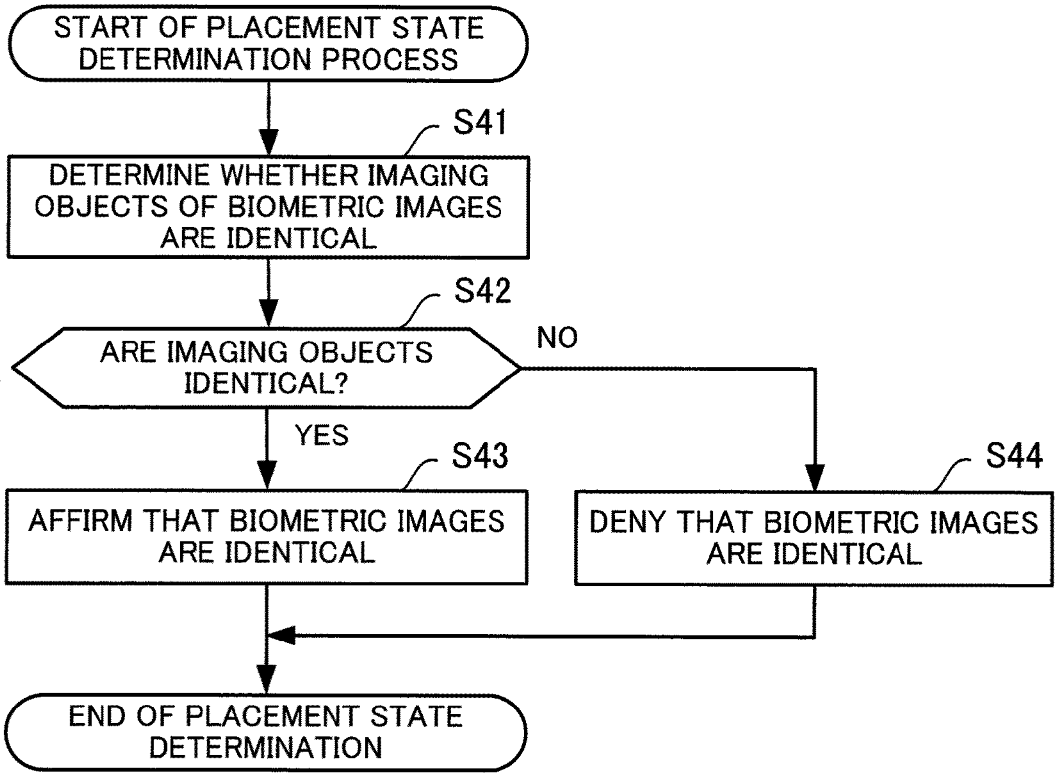
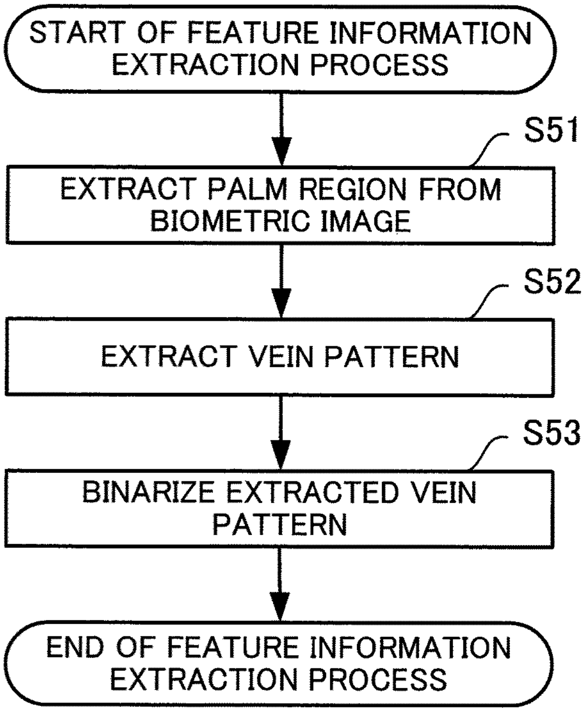

START OF PLACEMENT STATE DETERMINATION PROCESS
S41
DETERMINE WHETHER IMAGING OBJECTS OF BIOMETRIC IMAGES ARE IDENTICAL
S42
ARE IMAGING OBJECTS IDENTICAL?
NO
YES
S43
AFFIRM THAT BIOMETRIC IMAGES ARE IDENTICAL
S44
DENY THAT BIOMETRIC IMAGES ARE IDENTICAL
END OF PLACEMENT STATE DETERMINATION

FIG. 10


START OF FEATURE INFORMATION EXTRACTION PROCESS
S51
EXTRACT PALM REGION FROM BIOMETRIC IMAGE
S52
EXTRACT VEIN PATTERN
S53
BINARIZE EXTRACTED VEIN PATTERN
END OF FEATURE INFORMATION EXTRACTION PROCESS

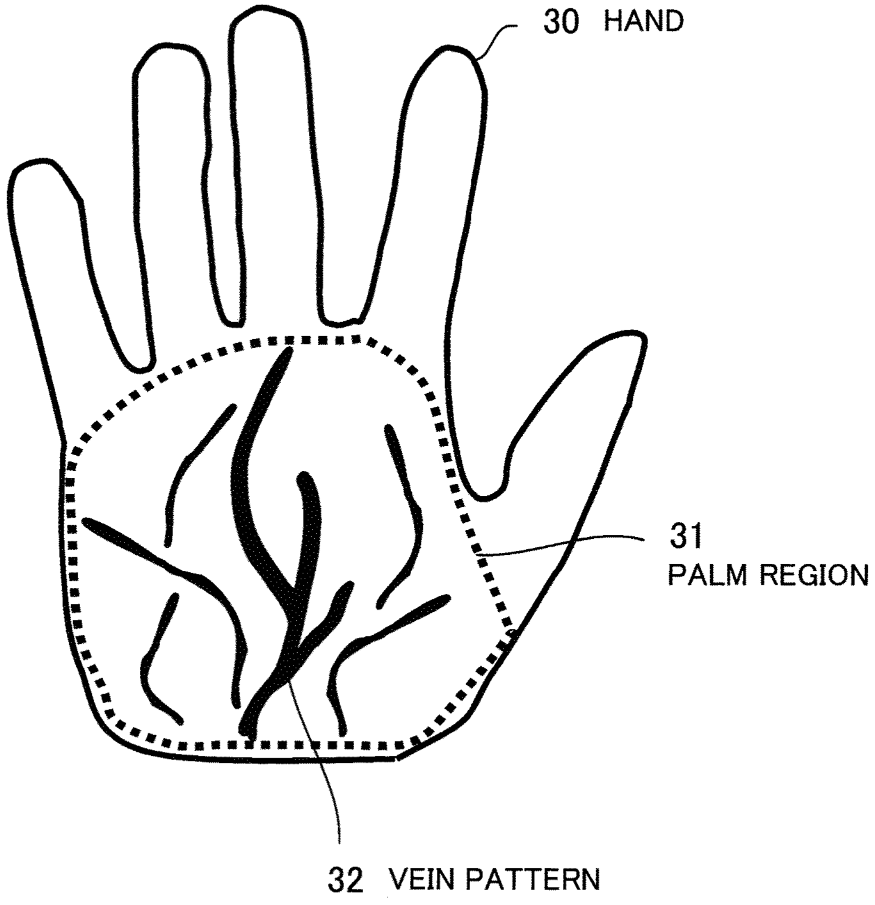


FIG. 11

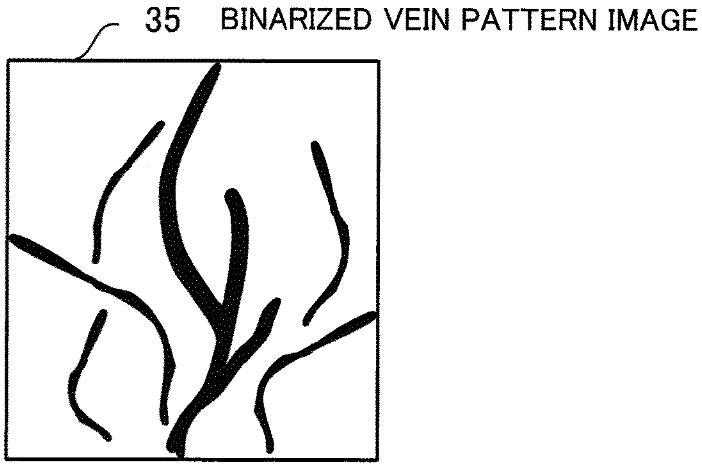


FIG. 12

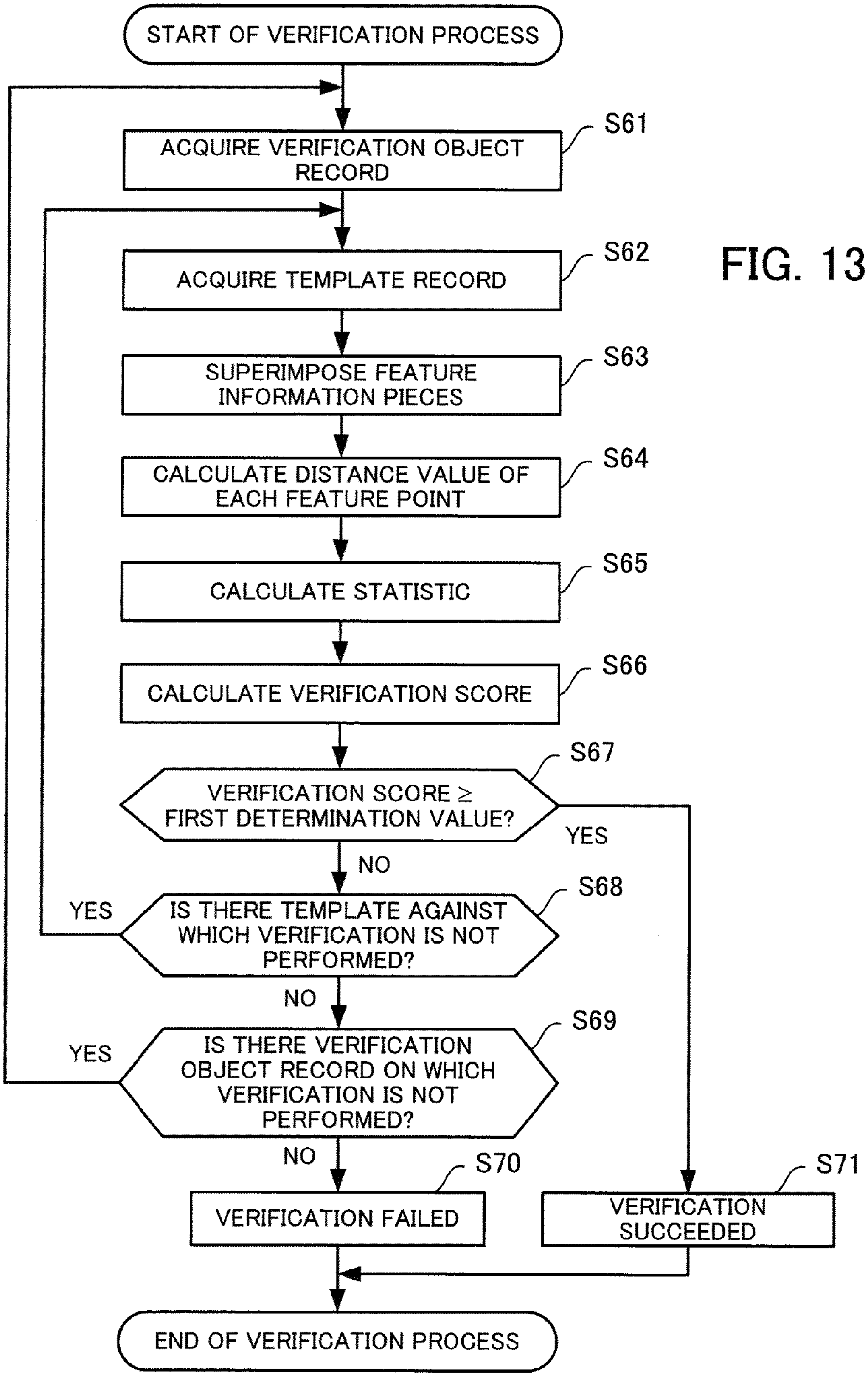
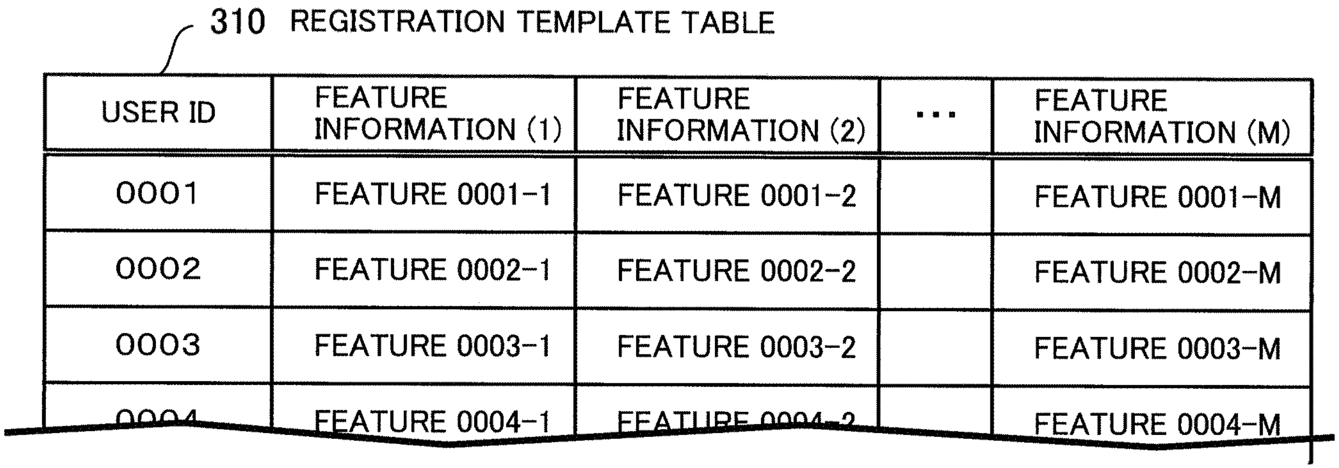

START OF VERIFICATION PROCESS
S61
ACQUIRE VERIFICATION OBJECT RECORD
S62
ACQUIRE TEMPLATE RECORD
S63
SUPERIMPOSE FEATURE INFORMATION PIECES
S64
CALCULATE DISTANCE VALUE OF EACH FEATURE POINT
S65
CALCULATE STATISTIC
S66
CALCULATE VERIFICATION SCORE
S67
VERIFICATION SCORE ≥ FIRST DETERMINATION VALUE?
YES
NO
S68
IS THERE TEMPLATE AGAINST WHICH VERIFICATION IS NOT PERFORMED?
YES
NO
S69
IS THERE VERIFICATION OBJECT RECORD ON WHICH VERIFICATION IS NOT PERFORMED?
YES
NO
S70
VERIFICATION FAILED
S71
VERIFICATION SUCCEEDED
END OF VERIFICATION PROCESS

FIG. 13



310 REGISTRATION TEMPLATE TABLE

USER ID	FEATURE INFORMATION (1)	FEATURE INFORMATION (2)	···	FEATURE INFORMATION (M)
0001	FEATURE 0001-1	FEATURE 0001-2		FEATURE 0001-M
0002	FEATURE 0002-1	FEATURE 0002-2		FEATURE 0002-M
0003	FEATURE 0003-1	FEATURE 0003-2		FEATURE 0003-M
0004	FEATURE 0004-1	FEATURE 0004-2		FEATURE 0004-M

FIG. 14

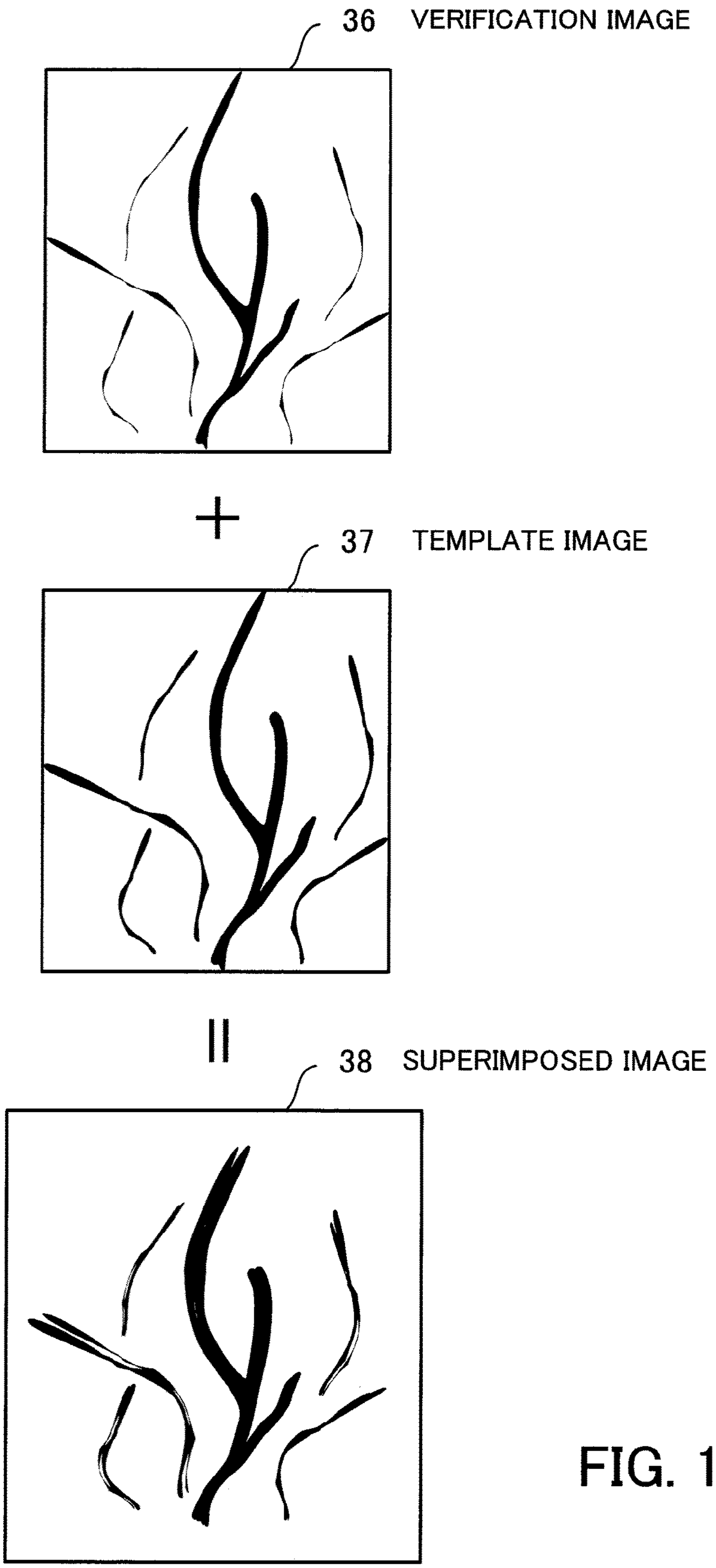
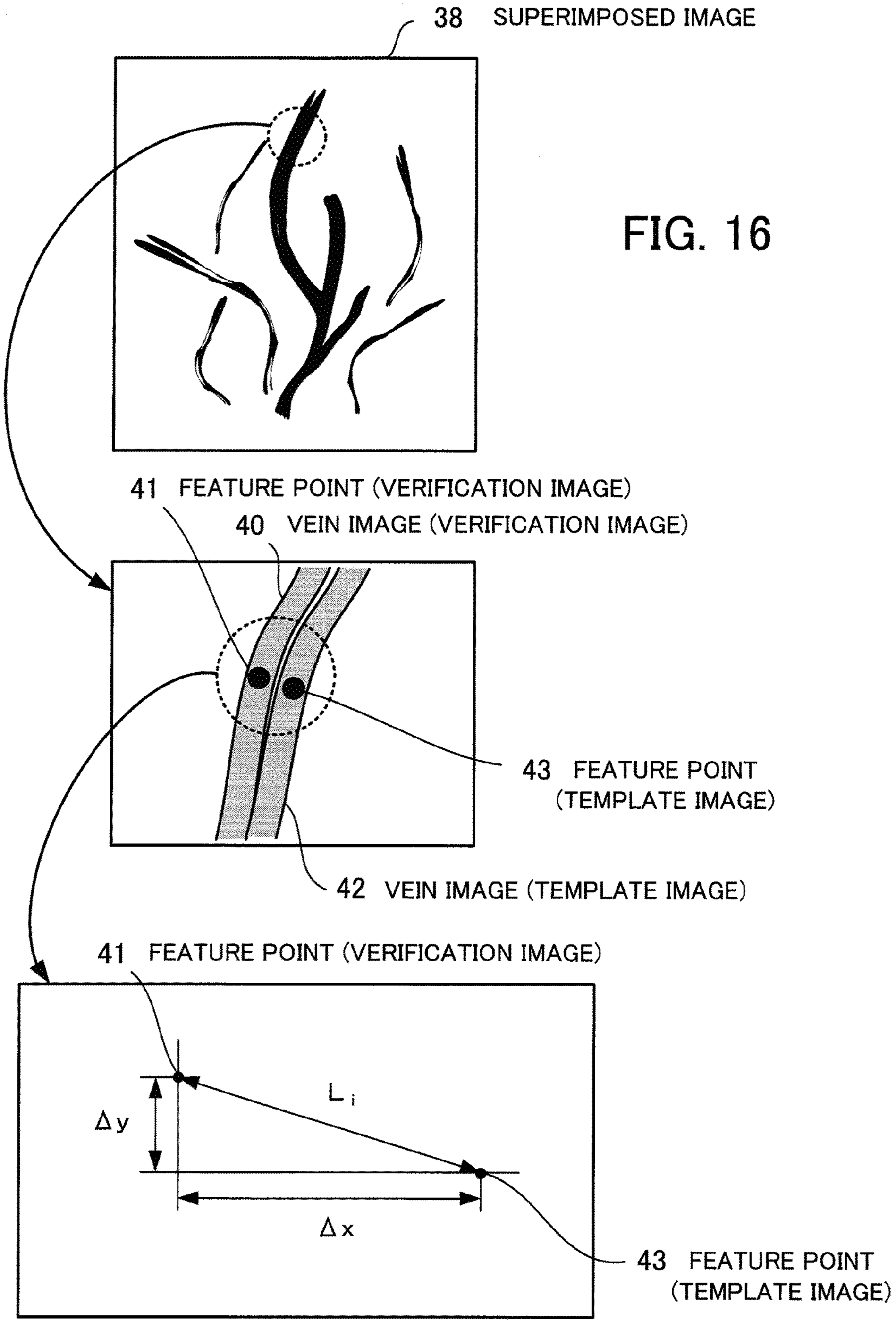

36 VERIFICATION IMAGE
+
37 TEMPLATE IMAGE
=
38 SUPERIMPOSED IMAGE

FIG. 15

FIG. 16

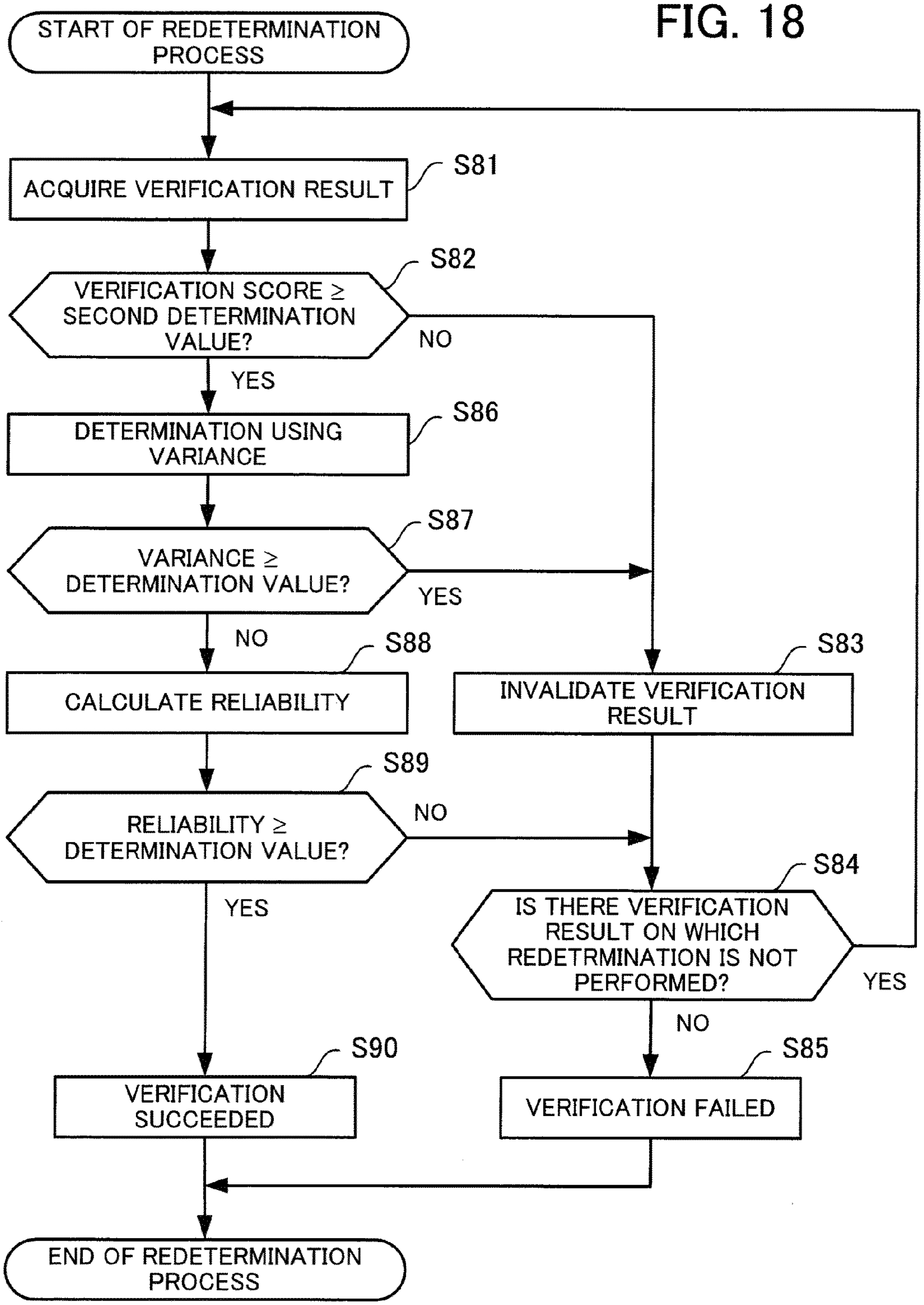

38 SUPERIMPOSED IMAGE
41 FEATURE POINT (VERIFICATION IMAGE)
40 VEIN IMAGE (VERIFICATION IMAGE)
43 FEATURE POINT (TEMPLATE IMAGE)
42 VEIN IMAGE (TEMPLATE IMAGE)
41 FEATURE POINT (VERIFICATION IMAGE)
L_i
Δy
Δx
43 FEATURE POINT (TEMPLATE IMAGE)

300 VERIFICATION RESULTS

VERIFICATION RESULT NO.	DISTANCE VARIANCE	VARIANCE DETERMINATION RESULT	VERIFICATION SCORE	RELIABILITY	CUMULATIVE RELIABILITY
0001	4210	NO	478	85. 333%	85. 333%
0002	5300	YES	422	—	—
0003	1020	NO	389	26. 000%	89. 147%
0004	2520	NO	412	41. 333%	93. 633%
0005	660	NO	452	68. 000%	97. 662%
0006	2220	NO	498	98. 667%	99. 973%
0007	4902	YES	480	—	—
0008	1153	NO	477	84. 667%	99. 996%
0009	1852	NO	395	70. 000%	99. 997%

FIG. 17

FIG. 18


START OF REDETERMINATION PROCESS
ACQUIRE VERIFICATION RESULT
S81
VERIFICATION SCORE ≥ SECOND DETERMINATION VALUE?
S82
NO
YES
DETERMINATION USING VARIANCE
S86
VARIANCE ≥ DETERMINATION VALUE?
S87
YES
NO
CALCULATE RELIABILITY
S88
INVALIDATE VERIFICATION RESULT
S83
RELIABILITY ≥ DETERMINATION VALUE?
S89
NO
YES
IS THERE VERIFICATION RESULT ON WHICH REDETRMINATION IS NOT PERFORMED?
S84
YES
NO
VERIFICATION SUCCEEDED
S90
VERIFICATION FAILED
S85
END OF REDETERMINATION PROCESS

VERIFICATION APPARATUS, VERIFICATION PROGRAM, AND VERIFICATION METHOD

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation application of International Application PCT/JP2011/056608 filed on Mar. 18, 2011 which designated the U.S., the entire contents of which are incorporated herein by reference.

FIELD

The present invention relates to a verification apparatus, a verification program, and a verification method.

BACKGROUND

The human body has biometric information that identifies an individual. Some types of biometric information are used for identifying and authenticating an individual. For example, it is known that biometric information that may be used for authentication includes fingerprints, retina, iris, face, blood vessels, deoxyribonucleic acid (DNA), and the like.

With the recent developments in biometric authentication technologies, various types of individual authentication apparatuses have become available. These apparatuses recognize the features of a living body, that is, a part of the human body, so as to authenticate an individual. For example, palm vein authentication technology is used in transactions in bank accounts, door security systems, log-in authentication in personal computers, and the like. In biometric authentication, biometric information acquired upon authentication is verified against biometric information acquired upon registration (registered template).

In order to improve the accuracy of authentication using biometric information, it is preferable to acquire biometric information of a certain level of accuracy each time authentication is performed. However, acquired biometric information is not always the same, and there is a change every time acquisition is performed. Therefore, verification of biometric information involves calculating a verification score that indicates the similarity between a registered template and the acquired biometric information, and comparing the calculated verification score with a determination value. There has been proposed a verification apparatus capable of, even if there is a change in the acquired biometric information, performing verification with high accuracy by correcting a verification score (see, for example, Japanese Laid-open Patent Publication No. 2008-40874).

However, since the amount of features contained in acquired biometric information varies between individuals, and the difficulty of authentication varies from user to user, regardless of the scheme of authentication. Further, for example, the amount of features that may be acquired from the biometric information also varies with the surrounding environment in which the biometric information is acquired, such as temperature, humidity, outside light, the position of the sensor, individual differences between sensors, and the like.

Accordingly, authenticating a specific user (who inherently has only a small amount of feature information, or who is not familiar with authentication) may be more difficult than authenticating other users. Similarly, authenticating a user in a specific environment may be more difficult than in other environments.

One of the issues in authentication technology is to reduce the difficulty in authenticating a user under such specific conditions so as to increase the authentication rate and thus to improve the usability.

SUMMARY

According to an aspect of the embodiments to be discussed herein, there is provided a verification apparatus that includes a memory configured to store a plurality of biometric information pieces acquired from a living body; and one or more processors configured to perform a procedure including: performing first verification on one or more of the plurality of biometric information pieces, using a preregistered verification information piece and a first determination value, and performing second verification on the plurality of biometric information pieces having a predetermined relationship, using the verification information piece and a second determination value which defines a less stringent criterion than the first determination value, when the first verification fails.

The object and advantages of the invention will be realized and attained by means of the elements and combinations particularly pointed out in the claims.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are not restrictive of the invention.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** illustrates the configuration of a verification apparatus according to a first embodiment;

FIG. **2** illustrates an example of distribution of verification scores of ordinary users calculated by the verification apparatus according to the first embodiment;

FIG. **3** illustrates an example of distribution of verification scores of certain users calculated by the verification apparatus according to the first embodiment;

FIG. **4** illustrates the overview of a verification apparatus according to a second embodiment;

FIG. **5** illustrates the hardware configuration of the verification apparatus according to the second embodiment;

FIG. **6** illustrates the configuration of a sensor unit according to the second embodiment;

FIG. **7** is a flowchart of an authentication process according to the second embodiment;

FIG. **8** is a flowchart of an attitude information acquisition process according to the second embodiment;

FIG. **9** is a flowchart of a placement state determination process according to the second embodiment;

FIG. **10** is a flowchart of a feature information extraction process according to the second embodiment;

FIG. **11** illustrates feature information extraction performed by the verification apparatus according to the second embodiment;

FIG. **12** illustrates an example of feature information extracted by the verification apparatus according to the second embodiment;

FIG. **13** is a flowchart of a verification process according to the second embodiment;

FIG. **14** illustrates an example of registered template table according to the second embodiment;

FIG. **15** illustrates verification performed by the verification apparatus according to the second embodiment;

FIG. **16** illustrates verification performed by the verification apparatus according to the second embodiment;

FIG. **17** illustrates exemplary verification results obtained by the verification apparatus according to the second embodiment; and

FIG. **18** is a flowchart of a redetermination process according to the second embodiment.

DESCRIPTION OF EMBODIMENTS

Embodiments will be explained below with reference to the accompanying drawings.

First Embodiment

First, a verification apparatus of a first embodiment will be described with reference to FIG. **1**. FIG. **1** illustrates the configuration of the verification apparatus according to the first embodiment.

A verification apparatus **1** acquires biometric information from a living body, and verifies the acquired biometric information against preregistered verification information. Biometric information may be acquired from a living body, and be used for identifying an individual.

The verification apparatus **1** includes a biometric information acquisition unit **2**, a first verification unit **3**, and a second verification unit **4**. The biometric information acquisition unit **2** acquires a biometric information piece **8** from a biometric information source part of a living body. The biometric information acquisition unit **2** acquires a plurality of biometric information pieces **8** by performing acquisition a plurality of times. The biometric information acquisition unit **2** acquires the plurality of biometric information pieces **8** from the same object (the same biometric information source part) at different timings.

The first verification unit **3** performs verification on the biometric information piece **8**, using a verification information piece **6** and a first determination value **5**. The first verification unit **3** calculates, as a verification score (similarity score), the similarity between the biometric information piece **8** and the verification information piece **6**. The first verification unit **3** compares the calculated verification score with the first determination value **5** so as to determine whether verification is successful, that is, so as to determine whether the biometric information piece **8** used for verification matches the verification information piece **6**. Then, the first verification unit **3** outputs the verification result. The verification information piece **6** is a preregistered biometric information piece, and is stored in a storage unit of the verification apparatus **1** or a storage unit of an external device (such as a computer, an IC card reader and writer, or the like, which is connected for communication). In the case where there are a plurality of biometric information pieces **8** and verification information pieces **6**, the first verification unit **3** may perform verification on an arbitrary combination of biometric information piece **8** and verification information piece **6**.

In the case where the verification by the first verification unit **3** has failed, the second verification unit **4** performs verification on the plurality of biometric information pieces **8** having a predetermined relationship, using the verification information piece **6** and a second determination value **7** which defines a less stringent criterion than the first determination value **5**. The plurality of biometric information pieces **8** on which the second verification unit **4** performs verification are those rejected by the verification performed by the first verification unit **3**. These plural biometric information pieces **8** have a predetermined relationship with a reduced risk of false acceptance. For example, these plural biometric information pieces **8** are information pieces that are ensured to have been acquired from the same living body. More specifically, these plural biometric information pieces **8** are information pieces that are acquired from continuously captured images of a living body, or information pieces remaining after statistically irrelevant data are removed.

The second verification unit **4** compares the verification score calculated by the first verification unit **3** with the second determination value **7**, and determines that the match is confirmed when a plurality of biometric information pieces **8** satisfy the criterion defined by the second determination value **7**. In this way, the second verification unit **4** evaluates a plurality of biometric information pieces **8**, and thereby prevents the accuracy from lowering due to the determination criterion for each biometric information piece **8** being less stringent. Thus, the second verification unit **4** achieves the overall target authentication accuracy of the verification apparatus **1**.

Accordingly, the verification apparatus **1** may increase the authentication rate of a user whose authentication by the first verification unit **3** is difficult, reduce the number of times that the user retries a verification operation, and improve the usability.

It is to be noted that the verification score is the degree of similarity between the biometric information piece **8** and the verification information piece **6** derived from a predetermined derivation method, and any known method may be used. Further, the first determination value **5** is a threshold that is set on the basis of a target authentication accuracy of the verification apparatus **1**, that is, a false rejection rate (FRR) and a false acceptance rate (FAR) that are acceptable. The second determination value **7** is a threshold defining a less stringent criterion than the first determination value **5**. When a less stringent determination criterion is used, the determination of whether verification is successful is made using a verification score indicating a degree of similarity less than the first determination value **5**. That is, the second determination value **7** is a threshold that indicates a lower false rejection rate than the first determination value **5**, and indicates a higher false acceptance rate than the first determination value **5**. In other words, the first determination value **5** is a threshold for determining whether the user is a rightful user, and the second determination value **7** is a threshold associated with an increased risk of false acceptance.

It is to be noted that, according to the testing and reporting method defined in ISO/IEC19795:2006, the false rejection rate (FRR) and the false acceptance rate (FAR) in authentication that involves acquiring biometric information n times are represented by the following expressions (1) and (2), respectively. Further, retrying verification usually improves the false rejection rate, but decreases the false acceptance rate.

$$\mathrm{FRR}(n)=\mathrm{FRR}^n \tag{1}$$

$$\mathrm{FAR}(n)=\mathrm{FAR}\times n \tag{2}$$

However, it is known from experience that the expressions (1) and (2) do not apply to the false rejection rate (FRR) and false acceptance rate (FAR) of approximately 10% of the users. The events of false rejection and false acceptance with respect to these certain users are not only due to probabilistic events, but also greatly due to other causes such as the acquired biometric information being biased.

Examples of distribution of verification scores are illustrated in FIGS. **2** and **3**. FIG. **2** illustrates an example of distribution of verification scores of ordinary users calculated by the verification apparatus according to the first embodiment. FIG. **3** illustrates an example of distribution of verification scores of certain users calculated by the verification apparatus according to the first embodiment. For example, the verification scores of the ordinary users are distributed as illustrated in FIG. **2**, and a greater number of users pass the verification using the first determination value.

On the other hand, the verification scores of the certain users are distributed as illustrated in FIG. **3**, and a relatively large number of users are rejected by the verification using the first determination value. These certain users have a certain number of verification scores that are distributed between the first determination value and the second determination value. Therefore, in the case where such a user has a plurality of scores in this range, even if the user passes the verification on the basis of a certain reliability level, it is possible to achieve the target authentication accuracy of the verification apparatus **1**.

Accordingly, as for the users who are rightful but are rejected by the verification, the verification apparatus **1** may allow a part (for example, 50%) of these users to pass the verification by the second verification unit **4**.

Second Embodiment

Next, a more specific example of verification apparatus will be described as a second embodiment. First, an overview of the verification apparatus will be described with reference to FIG. **4**. FIG. **4** illustrates the overview of the verification apparatus according to the second embodiment. Although a verification apparatus **10** that performs verification on the basis of palm veins is illustrated as the verification apparatus of the second embodiment, the present invention is not limited thereto. The verification apparatus may be implemented as an apparatus that performs verification on the basis of the features detected from other parts of a living body.

When authenticating a user, the verification apparatus **10** performs verification by comparing preregistered biometric information (registered template) and biometric information acquired by the verification apparatus **10**. The verification apparatus **10** is used when logging on to an information system or the like.

The verification apparatus **10** includes a processing device **11**, a display **12**, and a sensor-unit-embedded mouse **14**. The verification apparatus **10** may further include a keyboard **13**, an integrated circuit (IC) card reader and writer **15**, and the like, as needed. The sensor-unit-embedded mouse **14** serves as a mouse for receiving input operations, and includes a sensor unit that captures a palm vein image. The sensor unit includes an imaging device so as to capture a palm vein image of the user, and output the image to the processing device **11**. The IC card reader and writer **15** reads information from and writes information into an IC card **16** of the user. The keyboard **13** and the sensor-unit-embedded mouse **14** receive input operations.

The following describes a verification operation for palm vein authentication performed by the verification apparatus **10**. The user who requests authentication enters identification information for identifying the user (for example, a user ID) using the keyboard **13**, the sensor-unit-embedded mouse **14**, or the IC card reader and writer **15**. The verification apparatus **10** presents the user with an authentication procedure on the display **12**, and prompts the user to input biometric information for verification. The user inputs biometric information by placing the hand over the sensor-unit-embedded mouse **14**. Then, the verification apparatus **10** having received a palm vein image as biometric information verifies the input information against a registered template. The registered template may be acquired from a storage unit of the processing device **11**, a storage unit of an authentication server connected over a network, or a memory of the IC card **16** of the user.

For example, in the case where the verification apparatus **10** is for personal use, the verification apparatus **10** acquires a registered template from the storage unit of the processing device **11** or a memory of the IC card **16** of the user.

Next, an exemplary hardware configuration of the verification apparatus **10** of this embodiment will be described with reference to FIG. **5**. FIG. **5** illustrates the hardware configuration of the verification apparatus according to the second embodiment.

The entire operations of the verification apparatus **10** are controlled by a central processing unit (CPU) **101** of the processing device **11**. The CPU **101** is connected to a random access memory (RAM) **102**, a hard disk drive (HDD) **103**, a communication interface **104**, a graphic processor **105**, and an input and output interface **106** via a bus **107**.

The RAM **102** temporarily stores at least part of the operating system (OS) program and application programs that are executed by the CPU **101**. The RAM **102** also stores various types of data that are used for operations of the CPU **101**. The HDD **103** stores the OS and application programs.

The graphic processor **105** is connected to the display **12**. The graphic processor **105** displays an image on the screen of the display **12** in accordance with an instruction from the CPU **101**.

The input and output interface **106** is connected to the keyboard **13**, the sensor-unit-embedded mouse **14**, and the IC card reader and writer **15**. Further, the input and output interface **106** is connectable to a portable recording medium interface that is capable of writing information into a portable recording medium **110** and reading information from the portable recording medium **110**. The input and output interface **106** transmits signals, which are transmitted from the keyboard **13**, the sensor-unit-embedded mouse **14**, the IC card reader and writer **15**, and the portable recording medium interface, to the CPU **101** via the bus **107**.

The communication interface **104** is connected to a network **18**. The communication interface **104** transmits data to and receives data from another computer that is connected over a network.

With the hardware configuration described above, it is possible to realize the processing functions of this embodiment.

The processing device **11** may be formed of modules including a field programmable gate array (FPGA) and a digital signal processor (DSP), respectively, and may be configured without including the CPU **101**. In this case, the processing device **11** includes a non-volatile memory (for example, electrically erasable and programmable read only memory (EEPROM), flash memory, flash-memory-based memory card, or the like) and stores firmware of the modules. The firmware may be written in the non-volatile memory via the portable recording medium **110** or the communication interface **104**. In this way, the firmware of the processing device **11** may be updated by rewriting the firmware stored in the non-volatile memory.

Next, the sensor unit embedded in the sensor-unit-embedded mouse **14** will be described with reference to FIG. **6**. FIG. **6** illustrates the configuration of the sensor unit according to the second embodiment.

A sensor unit **20** is disposed at a portion of the sensor-unit-embedded mouse **14** which comes into contact with the palm when the mouse is operated. The sensor unit **20** acquires a palm vein image by capturing an image of the palm placed over the sensor-unit-embedded mouse **14** without being in contact therewith.

The sensor unit **20** includes a controller **21**, an imaging unit **22**, a distance measurement unit **23**, a storage unit **24**, and a communication unit **25**.

The controller **21** performs overall control of the processing units. The imaging unit **22** captures an image of a living body as an imaging object so as to acquire image information. The imaging unit **22** includes an image sensor (for example, complementary metal oxide semiconductor (CMOS) sensor, charge coupled device (CCD) sensor, or the like) that captures an image of the living body, a condenser lens, and a plurality of near-infrared light-emitting diodes (LED) that irradiate the imaging object. The near-infrared light-emitting diodes are disposed around the image sensor, for example, and emit near-infrared rays toward the imaging object (upward) such that the image sensor captures an image of the imaging object irradiated with the near-infrared rays. The imaging unit **22** is capable of continuously capturing images of the imaging object, and takes 15 frames per second, for example. The speed of capturing images may be changed in the settings. With regard to the timing of capturing images, the imaging unit **22** may capture an image in accordance with the distance to the imaging object on the basis of the output from the distance measurement unit **23**, regardless of time. It is to be noted that the imaging unit **22** has a configuration suitable for capturing images of palm veins. In the case of capturing images of another part of the living body, such as iris or the like, a configuration suitable for the imaging object may be employed.

The distance measurement unit **23** acquires distance information indicating the distance to the living body as an imaging object. The storage unit **24** stores the image information acquired by the imaging unit **22** and the distance information acquired by the distance measurement unit **23** in association with each other. The communication unit **25** is communicably connected to the processing device so as to receive instructions from the processing device **11** and transmit the image information and the distance information.

The image captured by the sensor unit **20** is an image obtained by irradiating the living body (palm) as an imaging object with near-infrared rays and capturing an image of a reflection light therefrom. The hemoglobin in the red blood cells flowing in the veins does not carry oxygen. Therefore, this hemoglobin (reduced hemoglobin) absorbs near-infrared rays at wavelengths near 700 through 1,000 nanometers. Accordingly, when near-infrared rays are made incident on the palm, reflection is weak only in the areas where veins are present. Thus, the position of the veins may be identified on the basis of the intensity of the reflected near-infrared rays. Using a predetermined light source makes it easy to extract feature information from the captured image, but the captured image becomes an achromatic image.

Next, an authentication process performed by the processing device **11** will be described with reference to FIG. **7**. FIG. **7** is a flowchart of an authentication process according to the second embodiment. The processing device **11** executes an authentication process in response to an authentication request received from the user.

(Step S**11**) The processing device **11** requests the sensor-unit-embedded mouse **14** for image information pieces (biometric images) of a palm vein image to be used for verification. The sensor-unit-embedded mouse **14** continuously captures images of the living body as an imaging object so as to acquire a plurality of image information pieces. Upon capturing an image of the living body, the sensor-unit-embedded mouse **14** measures the distance to the imaging object, and generates distance information of the imaging object. The sensor-unit-embedded mouse **14** alternately performs distance measurement and image capture. The sensor-unit-embedded mouse **14** outputs, to the processing device **11**, the plurality of image information pieces and distance information pieces generated before and after capture of each image information piece. For example, in the case where the sensor-unit-embedded mouse **14** captures 10 biometric images in a predetermined time period (for example, 1 second), the sensor-unit-embedded mouse **14** outputs **10** image information pieces and **11** (=10+1) distance information pieces. The processing device **11** acquires, from the sensor-unit-embedded mouse **14**, the plurality of image information pieces and the distance information pieces generated before and after capture of each image information piece.

(Step S**12**) The processing device **11** performs an attitude information acquisition process for acquiring palm attitude information from the acquired image information piece, and determining whether the attitude of the palm is appropriate for use in verification. The details of the attitude information acquisition process will be described below with reference to FIG. **8**.

(Step S**13**) The processing device **11** performs a placement state determination process for determining based on the acquired image information pieces and distance information whether the acquired image information pieces are acquired from a continuous palm placing motion. The details of the placement state determination process will be described below with reference to FIG. **9**.

(Step S**14**) The processing device **11** performs a feature information extraction process for extracting a feature information piece from the acquired image information piece. The details of the feature information extraction process will be described below with reference to FIGS. **10** through **12**.

(Step S**15**) The processing device **11** performs a verification process for verifying the extracted feature information piece against a registered template. The details of the verification process will be described below with reference to FIGS. **13** through **17**.

(Step S**16**) As a result of the verification process, if the processing device **11** determines that the verification has succeeded (verification: SUCCESS), the process proceeds to step S**20**. If the verification has failed (verification: FAILURE), the process proceeds to step S**17**.

(Step S**17**) The processing device **11** performs a redetermination process for performing redetermination on the image information pieces that are rejected in the verification process. In the redetermination process, although verification is performed using a less stringent determination criterion than that of the verification process, since determination is performed on a plurality of image information pieces, the authentication accuracy is prevented from lowering. The details of the redetermination process will be described below with reference to FIG. **18**.

(Step S**18**) As a result of the redetermination process by the processing device **11**, if the verification has succeeded, the process proceeds to step S**20**. If the verification has failed, the process proceeds to step S**19**.

(Step S**19**) The processing device **11** determines whether to retry verification. Determination of whether to perform a retry is made when the attitude of the palm is determined not to be appropriate for use in verification in the attitude information acquisition process; when the image information pieces are determined not to be acquired from a continuous hand placing motion in the placement state determination process; and when verification fails in the redetermination process. It is to be noted that the processing device **11** performs a retry if the number of times of retry is less than a predetermined number of times, and does not perform a retry if the number of times of retry has reached the predetermined number of times. If the processing device **11** determines to retry verification, the process proceeds to step S**11**. On the other hand, if the processing device **11** determines not to retry verification, the process proceeds to step S**21**.

(Step S**20**) In response to the successful verification, the processing device **11** determines that the user is authenticated, and performs an operation that is needed in response to the successful authentication. Then, the authentication process ends.

(Step S**21**) In response to the failed verification, the processing device **11** determines that the user is rejected, and performs an operation that is needed in response to the failed authentication. Then, the authentication process ends.

In this way, while maintaining a predetermined level of authentication accuracy, the verification apparatus **10** may increase the authentication rate of a user whose authentication by a verification process is difficult, by performing a redetermination process. Thus, the verification apparatus **10** reduces the number of times that the user retries a verification operation, and improves the usability.

It is to be noted that, although the processing device **11** is configured to acquire a plurality of image information pieces of the living body that are continuously captured by the sensor-unit-embedded mouse **14**, the processing device **11** may be configured to acquire a plurality of image information pieces that are captured at the same time by a plurality of sensor units. In this case, the verification apparatus **10** may include a plurality of sensor units in place of the sensor-unit-embedded mouse **14**. Alternatively, the verification apparatus **10** may be configured such that the sensor unit of the sensor-unit-embedded mouse **14** includes a plurality of imaging devices so as to acquire a plurality of image information pieces at the same time.

In this way, the verification apparatus **10** may easily ensure that the imaging objects of the plurality of image information pieces are identical to each other.

Next, an attitude information acquisition process performed by the processing device **11** will be described with reference to FIG. **8**. FIG. **8** is a flowchart of an attitude information acquisition process according to the second embodiment. The processing device **11** acquires, from the sensor-unit-embedded mouse **14**, a plurality of image information pieces and distance information pieces generated before and after capture of each image information piece, and performs an attitude information acquisition process.

(Step S**31**) The processing device **11** extracts a palm region from each of the acquired image information pieces. For example, extraction of a palm region is performed by binarizing the image information piece and then performing morphology contour extraction. It is to be noted that extraction of a palm region may be performed by any other method than morphology contour extraction.

(Step S**32**) The processing device **11** calculates a distance value of each pixel in the palm region extracted from each of the acquired image information pieces. For example, the distance value of each pixel in the palm region may be calculated from the luminance value of each pixel in the palm region in the captured image, on the basis of the relationship between luminance and distance.

(Step S**33**) The processing device **11** calculates the attitude information of the palm using plane approximation. Calculation of attitude information is performed by recognizing the palm as a plane (plane approximation). The processing device **11** calculates, as attitude information, the inclination angles of the approximated plane in the horizontal and vertical directions on the basis of the distance value of each pixel.

(Step S**34**) The processing device **11** calculates the inclination angles of the approximated plane in the horizontal and vertical directions for each of the continuously acquired image information pieces.

(Step S**35**) The processing device **11** determines whether the calculated inclination angles are in an effective range. For example, the processing device **11** determines that the image information piece is valid if each of the inclination angles of the approximated plane in the horizontal and vertical directions is within a range of plus or minus 15 degrees, and determines that the image information piece is invalid if the inclination is excessively large.

If the processing device **11** determines that, in all the continuously acquired image information pieces, the inclination angles of the approximated plane in the horizontal and vertical directions are within the effective range, the attitude information acquisition process ends. On the other hand, if the processing device determines that the continuously acquired image information pieces include an image information piece in which the inclination angles of the approximated plane in the horizontal and vertical directions are out of the effective range, the process proceeds to step S**36**.

(Step S**36**) The processing device **11** outputs a guidance message for guiding the palm to an appropriate position. The guidance message is output by displaying guidance on the display **12**. The guidance message may be an audio message output from a speaker (not illustrated). After the processing device **11** outputs the guidance message, the attitude information acquisition process ends.

In this way, the verification apparatus **10** may correct the inappropriate attitude of the palm to an appropriate attitude. Thus, the verification apparatus **10** may acquire, as an image information piece to be used for verification, an image information piece in which the palm is in an appropriate attitude.

It is to be noted that, although the processing device **11** is configured to output a guidance message if any of the continuously acquired image information pieces are out of the effective range, the processing device **11** may be configured not to output a guidance message if a predetermined number of consecutive image information pieces of the continuously acquired image information pieces are in the effective range. For example, the processing device **11** may be configured not to output a guidance message if eight consecutive image information pieces of the ten continuously acquired image information pieces are in the effective range.

Next, a placement state determination process performed by the processing device **11** will be described with reference to FIG. **9**. FIG. **9** is a flowchart of a placement state determination process according to the second embodiment. The processing device **11** performs a placement state determination process for determining whether the plurality of image information pieces acquired from the sensor-unit-embedded mouse **14** are acquired from a continuous palm placing motion.

(Step S**41**) The processing device **11** determines whether imaging objects of a plurality image information pieces (biometric images) are identical to each other. In other words, the processing device **11** determines whether the hand of a same person is continuously placed over the sensor-unit-embedded mouse **14**.

More specifically, the processing device **11** calculates the distance to the palm at the time each image information piece is captured, on the basis of the image information pieces and the distance information pieces acquired from the sensor-unit-embedded mouse **14**. The processing device **11** determines whether there is no discontinuity in the time interval in which the image information pieces are captured, on the basis of the distances corresponding to the image information pieces. For example, in the case where the difference between the distances corresponding to two consecutive image information pieces is greater than a predetermined threshold, the processing device **11** determines that there is no continuity between the two consecutive images information pieces, that is, the two consecutive image information pieces are not generated from a continuous hand placing motion.

It is to be noted that determination of whether the imaging objects are identical may be performed on the basis of the shape of the hand, position (horizontal direction), orientation, angle, and the like.

(Step S**42**) If the processing device **11** determines that the imaging objects of the plurality of image information pieces are identical, the process proceeds to step S**43**. If the imaging objects are not identical, the process proceeds to step S**44**.

(Step S**43**) The processing device **11** affirms that the imaging objects of the plurality of image information pieces are identical. Thus, the placement state determination process ends.

(Step S**44**) The processing device **11** denies that the imaging objects of the plurality of image information pieces are identical. Thus, the placement state determination process ends.

In this way, the verification apparatus **10** prevents biometric information of another person generated intentionally or accidentally from being accepted. It is to be noted that the verification apparatus **10** may omit the placement state determination process if the imaging objects of a plurality of image information pieces have been ensured to be identical to each other based on the environment in which the images of the living body are captured. For example, the verification apparatus **10** may omit the placement state determination process if a sensor unit is provided that captures the image of a living body while holding the living body in a fixed state, or if the verification apparatus **10** is used in an environment in which a third party monitors the image capturing of the living body.

Next, a feature information extraction process performed by the processing device **11** will be described with reference to FIGS. **10** through **12**. FIG. **10** is a flowchart of a feature information extraction process according to the second embodiment. FIG. **11** illustrates feature information extraction performed by the verification apparatus according to the second embodiment. FIG. **12** illustrates an example of feature information piece extracted by the verification apparatus according to the second embodiment. The processing device **11** performs a feature information extraction process for extracting a feature information piece from each of the acquired image information pieces.

(Step S**51**) The processing device **11** extracts a palm region **31** from a hand **30** (see FIG. **11**) as the imaging object in each of the plurality of image information pieces (biometric information pieces). The processing device **11** may extract the palm region **31** in the same manner as in step S**31** of the attitude information acquisition process.

(Step S**52**) The processing device **11** extracts a vein pattern **32** from the extracted palm region **31**.

(Step S**53**) The processing device **11** binarizes the extracted vein pattern **32** so as to generate a binarized vein pattern image **35** (see FIG. **12**). Thus, the feature information extraction process ends.

The thus obtained binarized vein pattern image is verified as feature information against the registered template. It is to be noted that binarization of the vein pattern **32** is normalization of feature information for facilitating comparison and verification with the registered template. A normalization operation may be an operation other than binarization, such as thinning or the like, or may be a combination of a plurality of operations such as binarization and thinning.

Next, the authentication process performed by the processing device **11** will be described with reference to FIGS. **13** through **17**. FIG. **13** is a flowchart of a verification process according to the second embodiment. FIG. **14** illustrates an example of registered template table according to the second embodiment. FIG. **15** illustrates verification performed by the verification apparatus according to the second embodiment. FIG. **16** illustrates verification performed by the verification apparatus according to the second embodiment. FIG. **17** illustrates exemplary verification results obtained by the verification apparatus according to the second embodiment. The processing device **11** performs a verification process for verifying an extracted feature information piece against a registered template.

(Step S**61**) The processing device **11** acquires, as a verification object record, a feature information piece of one of the plurality of image information pieces which is generated in the feature information extraction process.

(Step S**62**) The processing device **11** acquires a feature information piece of a registered template, as a template record. More specifically, one or more template records are registered for each user in a registered template table **310** (see FIG. **14**). For example, for the user ID “0001”, “FEATURE 0001-1”, “FEATURE 0001-2”, . . . , and “FEATURE 0001-M” are registered as template records (feature information pieces). In the case where there are a plurality of feature information pieces that are registered as templates, the processing device **11** acquires one of the feature information pieces.

(Step S**63**) The processing device **11** superimposes one feature information piece subject to verification and one feature information piece registered as a template. More specifically, as illustrated in FIG. **15**, the feature information piece subject to verification and the feature information piece registered as a template are superimposed in a manner such that a verification image **36** and a template image **37** are superimposed so as to obtain a superimposed image **38**.

(Step S**64**) The processing device **11** calculates a distance value of each feature point in the feature information piece subject to verification and the feature information piece registered as a template. More specifically, as illustrated in FIG. **16**, the processing device **11** traces a vein image (verification image) **40**, and calculates a distance value of each feature point to a proximal point of a vein image (template image) **42**. A distance value L_i between a feature point (verification image) **41** and a feature point (template image) **43** is represented by the following expression (3):

$$L_i=\sqrt{(\Delta x^2+\Delta y^2)} \tag{3}$$

where Δx is the difference in x-component, and Δy is the difference in y-component.

In this way, the processing device **11** calculates the distance values of all the feature points in the verification image **36**.

(Step S**65**) The processing device **11** calculates a statistic for the calculated distance values. More specifically, in the case where there are n feature points, the processing device **11** calculates a sum Ls using an expression (4), calculates a mean value Lm using an expression (5), and calculates a variance V^2 using an expression (6). It is to be noted that calculation of a variance V^2 may be performed only when an expression (7) is satisfied. In this way, the processing device **11** may calculate a variance only for feature points having a large variance, that is, points where the displacement between the vein patterns is equal to a predetermined value c or greater. Thus, the processing device **11** may exclude the verification results obtained from poor extraction results due to noise, the attitude of the placed hand, or the like, from evaluation.

$$Ls = \sum_{i=0}^{n} L_i \tag{4}$$

$$Lm = \frac{L}{n} \tag{5}$$

$$V^2 = \frac{1}{n}\sum_{i=0}^{n} (L_i - Lm)^2 \tag{6}$$

$$(L_i - Lm)^2 \geq \varepsilon \tag{7}$$

(Step **S66**) The processing device **11** calculates a verification score on the basis of the calculated statistic. The verification score is an index for evaluating the similarity of a feature information piece subject to verification to a feature information piece registered as a template, and is represented by a value in the range from 0 to 1,200. The greater the verification score is, the higher the similarity of the feature information piece subject to verification to the feature information piece is. FIG. **17** illustrates an example of verification scores calculated in the manner described above. For example, the verification result number "0001" has a verification score "478".

(Step **S67**) The processing device **11** compares the calculated verification score with a first determination value. If the processing device **11** determines that the calculated verification score is equal to or greater than the first determination value, the process proceeds to step **S71**. If the calculated verification score is less than the first determination value, the process proceeds to step **S68**.

The first determination value is a threshold that is set on the basis of a target authentication accuracy of the verification apparatus **10**, that is, a false rejection rate (FRR) and a false acceptance rate (FAR) that are acceptable. For example, the first determination value is set to "500".

(Step **S68**) The processing device **11** determines whether there is a template record against which verification of the feature information piece acquired in step **S61** is not yet performed. If the processing device **11** determines that there is a template record against which verification is not yet performed, the process proceeds to step **S62**. If there is no template record against which verification is not yet performed, the process proceeds to step **S69**.

For example, in the case of the user ID "0001", the processing device **11** determines whether verification is performed against all the template records: "FEATURE 0001-1", "FEATURE 0001-2", . . . , and "FEATURE 0001-M". In this way, if there are m template records, the processing device **11** performs verification m times for one feature information piece subject to verification, and obtains m verification results.

(Step **S69**) The processing device **11** determines whether, among the plurality of image information pieces, there is a feature information piece that is not acquired as a verification object record. If the processing device **11** determines that there is a verification object record on which verification is not yet performed, the process proceeds to step **S61**. If there is no verification object record on which verification is not yet performed, the process proceeds to step **S70**.

(Step **S70**) The processing device **11** determines that the verification using the first determination value has failed (verification: FAILURE). Thus, the verification process ends.

(Step **S71**) The processing device **11** determines that the verification using the first determination value has succeeded (verification: SUCCESS). Thus, the verification process ends.

In this way, in the case where the verification using the first determination value has failed, the processing device **11** obtains verification results of a plurality of combinations of verification object record and template record. For example, in the case where n image information pieces are continuously acquired from the user ID "0001", verification is performed m times for each of feature information pieces generated from the respective image information pieces, so that a maximum of m×n verification results are obtained.

As illustrated in verification results **300**, the processing device **11** attaches a verification result number to each of the thus obtained verification results. Then, the processing device **11** stores a verification score and a distance variance for each verification result number. The verification results **300** illustrate an example in which there are three template records and three image information pieces. In the verification results **300**, since there are three template records and three image information pieces, there are 9 (=3×3) verification results.

It is to be noted that, although the processing device **11** performs verification using m templates records, verification may be performed using a single template. Alternatively, in the case where there are m template records, the processing device **11** may perform verification using j (j≤m) template records.

Next, a redetermination process performed by the processing device **11** will be described with reference to FIG. **18**. FIG. **18** is a flowchart of a redetermination process according to the second embodiment. The processing device **11** performs a redetermination process for performing redetermination for image information pieces that are rejected in the verification process.

(Step **S81**) The processing device **11** acquires, as a redetermination object record, one of verification results that are rejected in the verification process.

(Step **S82**) The processing device **11** compares the verification score of the verification result subject to redetermination with a second determination value. If the processing device **11** determines that the verification score of the verification result subject to redetermination is equal to or greater than the second determination value, the process proceeds to step **S86**. If the verification score of the verification result subject to redetermination is less than the second determination value, the process proceeds to step **S83**.

The second determination value is a threshold that is set on the basis of an authentication accuracy that is not acceptable by the verification apparatus **10**, that is, false rejection rate (FRR) and false acceptance rate (FAR) that are unacceptable. For example, the second determination value is set to "350". The second determination value is based on a less stringent criterion than that of the first determination value. In this embodiment, the first determination value is greater than the second determination value.

(Step **S83**) The processing device **11** invalidates the verification result subject to redetermination. Invalidation of such a verification result subject to redetermination makes it possible to remove instable verification results and thereby to improve the accuracy of redetermination.

(Step **S84**) The processing device **11** determines whether, among the verification results that are rejected in the verification process, there is a verification result on which redetermination is not performed. If the processing device **11** determines that there is a verification result on which redetermination is not performed, the process proceeds to step **S81**. If there is no verification result on which redetermination is not performed, the process proceeds to step **S85**.

(Step **S85**) The processing device **11** determines that the redetermination has failed (verification: FAILURE). Thus, the redetermination process ends.

(Step **S86**) The processing device **11** compares the distance variance of the verification result subject to redetermination with a third determination value. The third determination value (variance determination threshold) is a preset value, and is a statistically calculated distance variance value that is associated with a predetermined risk of false acceptance. In this embodiment, the third determination value is set to "4,800".

The processing device **11** stores a comparison result between the distance variance of the verification result subject to redetermination and the third determination value, in the verification results **300** as a variance determination result. The processing device **11** stores "YES" in the verification results **300** if the distance variance of the verification result subject to redetermination is equal to or greater than the third determination value, and stores "NO" in the verification results **300** if the distance variance of the verification result subject to redetermination is less than the third determination value.

(Step **S87**) If the processing device **11** determines that the distance variance of the verification result subject to redetermination is equal to or greater than the third determination value, the process proceeds to step **S83**, in which the processing device **11** invalidates the verification result whose distance variance is equal to or greater than the third determination value. On the other hand, if the distance variance of the verification result subject to redetermination is less than the third determination value, the process proceeds to step **S88**.

In this way, in the case where the distance variance of a verification result subject to redetermination is equal to or greater than the third determination value, the verification apparatus **10** invalidates the verification result, and thus prevents false acceptance of a user having similar features.

(Step **S88**) The processing device **11** calculates the reliability of the verification result subject to redetermination, using an expression (8).

$$S_i=(M_i-TH2)/(TH1-TH2) \tag{8}$$

where S_i is the reliability of the i-th verification result; M_i is the verification score of the i-th result; TH**1** is the first determination value; and TH**2** is the second determination value.

Further, the processing device **11** calculates the cumulative reliability of the verification results that have been subject to redetermination, using an expression (9). For example, according to the verification results **300**, the reliability S_i of the verification result number "0001" is "85.333%", and the cumulative reliability S is "85.333% (=1−(1−0.853))". Further, the reliability S_3 of the verification result number "0003" is "26.000%", and the cumulative reliability S is "89.147% (=1−(1−0.85333)(1−0.26000))". In this way, if there are i verification results that have been subject to redetermination, the cumulative reliability is calculated on the basis of i reliabilities.

$$S=1-(1-S_1)(1-S_2)\ldots(1-S_{n-1})\times(1-S_n) \tag{9}$$

(Step **S89**) If the processing device **11** determines that the cumulative reliability of the verification results that have been subject to redetermination is equal to or greater than a fourth determination value, the process proceeds to step **S90**. If the cumulative reliability of the verification results that have been subject to redetermination is less than the fourth determination value, the process proceeds to step **S84**.

The fourth determination value (reliability determination threshold) is a preset value. In this embodiment, the fourth determination value is set to "99.000%".

(Step **S90**) The processing device **11** determines that the verification using the fourth determination value has succeeded (verification: SUCCESS). Thus, the redetermination process ends. According to the fourth determination value "99.000%" in the verification results **300**, when redetermination is performed on the verification result number "0006", the obtained cumulative reliability is "99.973%", and hence the processing device **11** determines that the verification has succeeded.

In this way, in the case where the imaging objects of the plurality of image information pieces are ensured to be identical, the verification apparatus **10** performs redetermination on a set of reliabilities calculated from the verification scores of the verification results so as to improve the accuracy of user authentication.

It is to be noted that although the processing device **11** acquires redetermination object records in verification result number order, the processing device **11** may acquire redetermination object records after sorting the records by verification score or distance variance.

It is to be noted that the verification apparatus **10** may be implemented as an automated teller machine (ATM) installed in a financial institution, and a verification apparatus of a room access control system installed at the entrance of a room.

The above-described processing functions may be implemented on a computer. In this case, a program describing the functions of each device is provided. The computer executes the program, so that the above-described processing functions are implemented on the computer. The program may be stored in a computer-readable recording medium (including a portable recording medium). Examples of computer-readable recording media include magnetic storage devices, optical discs, magneto-optical storage media, semiconductor memories, and the like. Examples of magnetic storage devices include hard disk drives (HDDs), flexible disks (FDs), magnetic tapes, and the like. Examples of optical discs include digital versatile discs (DVDs), DVD-RAMs, CD-ROMs, compact disc-recordable/rewritables (CD-R/RWs), and the like. Examples of magneto-optical storage media include magneto-optical disks (MOs) and the like.

Portable storage media, such as DVD and CD-ROM, are used for distribution of the program. Further, the program may be stored in a storage device of a server computer so as to be transmitted from the server computer to other computers via a network.

A computer which is to execute the program stores, in its storage device, the program recorded on a portable storage medium or the program transmitted from a server computer. Then, the computer reads the program from its storage device and performs processing in accordance with the program. The computer may read the program directly from the portable recording medium, and execute processing in accordance with the program. Alternatively, the computer may sequentially receive the program from the server computer and execute processing in accordance with the received program.

It is to be noted that although the palm is illustrated as the body surface in the above embodiments, the body surface is not limited thereto and may be the surface of any part of the body. For example, the body surface may be of the sole of the foot, finger, toe, the back of the hand, the instep of the foot, wrist, arm, and the like.

In the case where the information on veins is used for biometric authentication, the body surface may be the surface of any part where veins are observable. It is advantageous to acquire biometric information from the surface of a body part whose location is identifiable. For example, in the case where biometric information is acquired from the palm or the face, it is possible to identify the location from which the biometric information is acquired, on the basis of the acquired image.

Further, the biometric information to be used for authentication is not limited to information on veins, and may include other types of information such as information on fingerprints, handprints, and the like.

The above-described verification apparatus, verification program, and verification method are capable of reducing the difficulty in authenticating a user under specific conditions so as to increase the authentication rate and thus to improve the usability.

All examples and conditional language provided herein are intended for the pedagogical purposes of aiding the reader in understanding the invention and the concepts contributed by the inventor to further the art, and are not to be construed as limitations to such specifically recited examples and conditions, nor does the organization of such examples in the specification relate to a showing of the superiority and inferiority of the invention. Although one or more embodiments of the present invention have been described in detail, it should be understood that various changes, substitutions, and alterations could be made hereto without departing from the spirit and scope of the invention.

What is claimed is:

1. A verification apparatus comprising:

a memory configured to store a plurality of biometric information pieces acquired from a same biometric information source part; and

one or more processors configured to perform a procedure including:

performing first verification on one of the plurality of biometric information pieces, using a preregistered verification information piece and a first determination value, and

performing second verification on the plurality of biometric information pieces having a predetermined relationship, using the verification information piece and a second determination value which defines a less stringent criterion than the first determination value, when the first verification fails.

2. The verification apparatus according to claim **1**, wherein the performing second verification includes determining that the verification has succeeded when there are a plurality of biometric information pieces that do not satisfy the first determination value but satisfy the second determination value.

3. The verification apparatus according to claim **2**, wherein:

the procedure further includes determining whether the plurality of biometric information pieces are acquired from a same person; and

the performing second verification includes performing verification on the plurality of biometric information pieces that are determined to be acquired from a same person.

4. The verification apparatus according to claim **1**, wherein the plurality of biometric information pieces are acquired from a same person.

5. A non-transitory computer-readable storage medium storing a verification program, the verification program causing a computer to perform a procedure comprising:

performing first verification on one of a plurality of biometric information pieces acquired from a same biometric information source part, using a preregistered verification information piece and a first determination value; and

performing second verification on the plurality of biometric information pieces having a predetermined relationship, using the verification information piece and a second determination value which defines a less stringent criterion than the first determination value, when the first verification fails.

6. A verification method comprising:

performing, by a processor, first verification on one of a plurality of biometric information pieces acquired from a same biometric information source part, using a preregistered verification information piece and a first determination value; and

performing, by the processor, second verification on the plurality of biometric information pieces having a predetermined relationship, using the verification information piece and a second determination value which defines a less stringent criterion than the first determination value, when the first verification fails.

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